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Cosmos, climate and culture: Manchester meteorology made universal

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This article draws a historical connection between Victorian meteorological investigations in north-west England and the wider operations of the universe. It shows how, in the second half of the nineteenth century, a number of Mancunians helped to forge a radically new form of 'cosmical meteorology'[2] on just that basis. The foremost among these was Joseph Baxendell (1815–1887), astronomer to the Manchester Corporation, 1857–1871, and to the Southport Corporation thereafter. Two other major characters were both physicists at Owens College, Manchester: Balfour Stewart (1828–1887) and Arthur Schuster (1851–1934). All three were linked through their involvement with the Manchester Literary and Philosophical Society (MLPS), at which each presented important research on the relationship between meteorology, terrestrial magnetism and sunspots, much of it subsequently published in the MLPS *Proceedings* or *Memoirs*.[3] I show how Baxendell and Stewart promoted cosmical meteorology through this important regional periodical, as well as other local and national media from the 1860s until their coincident deaths in 1887. I conclude with a brief discussion of how Schuster sustained this much-criticized project in a less ambitious form at what later became the University of Manchester.[4]

Joseph Baxendell, corporate astronomy and weather troubles

From the point of view of history of science and culture in the Manchester region, Joseph Baxendell is an important and interesting character. Although his adult career was located in the north west his meteorological and astronomical work was of both national and international significance. Born on 19 April 1815 at Bank Top, Manchester, Baxendell attended Thomas Whalley's school at Cheetham Hill but was largely self-educated thereafter in mathematical and observational sciences. Both biographical and institutional forces drew him to correlated researches in meteorology and astronomy. From the ages of 14 to 20 he served as an ordinary sailor on the *Mary Scott* in trading trips to South America, gaining the mariner's intimate appreciation of weather patterns. It was apparently some 'casual remarks from his officers on matters of navigation' that inspired him to study the natural world, and thus as a teenager to develop the skills in observation for which he became renowned.[5]

Baxendell returned to Manchester in 1835, first assisting his father as a land steward before developing an independent business as an estate agent. He habitually dedicated his spare hours to astronomy, especially assisting his friend Robert Worthington (who had been accidentally blinded in one eye) in operating a five-inch refracting telescope at the latter's private observatory at Crumpsall Hall, near Manchester. By identifying and studying as many as 18 hitherto unknown variable stars in ensuing decades, Baxendell eventually became one of Britain's pre-eminent systematic observers in the field.[6] After a decade of nightly telescopic work the retiring autodidact finally took his work into a public forum by submitting his observations on ë Tauri[7] to the Royal Astronomical Society (RAS). Nearly another decade passed before Baxendell published again, four of his papers on variable stars appearing in the *Monthly Notices* of the RAS between 1855 and 1857; on the strength of these Baxendell was elected a Fellow of the RAS in 1858.[8] In that year he was also elected a Fellow of the MLPS, having recently presented further astronomical findings on variable stars in the series of MLPS *Proceedings* launched in 1860.[9] With his new credentials as a nationally and locally acknowledged observer of the heavens, he was appointed Astronomer to the Corporation of Manchester in 1859. As a post carrying an honorarium of a mere £40 a year – considerably less than an ordinary labourer's annual earnings – its holder was presumptively a gentleman specialist of independent means.

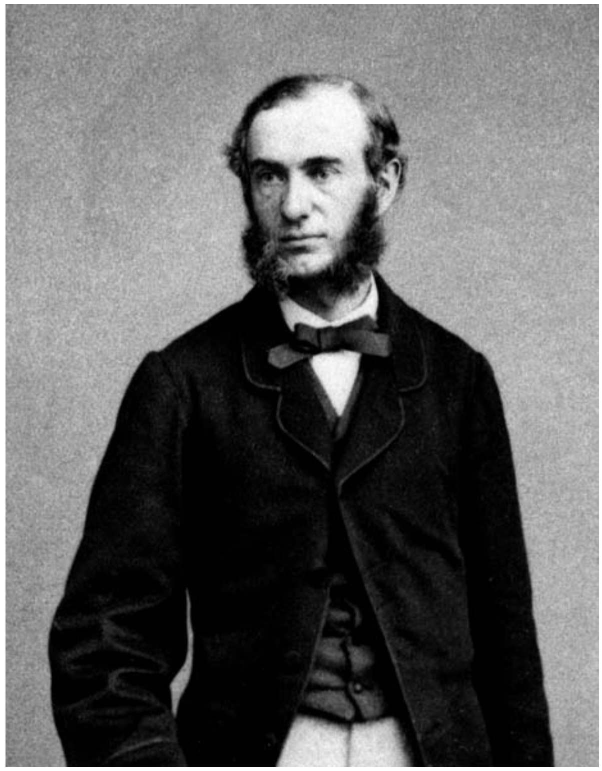
To understand why this post existed at all, though, we need to consider the local and national context of Manchester as a city increasingly connected to the rest of Britain via a burgeoning rail network. In 1847 the City of Manchester Corporation took upon itself a duty to provide civic notification of London Greenwich time, thereby displacing Manchester 'solar' time as the reference for local business and railway transactions. The traditional profusion of different local times across the British Isles generated not only dangers for the minute scheduling of railway signalling, but also a confusion over timetables that frequently led passengers to miss trains. Five years after the Great Western Railway introduced standard London time for all its services in 1840, the Liverpool and Manchester Railway Company petitioned Parliament for a single uniform time to be imposed on all businesses. This was not legally implemented until 1880 and indeed it was initially strictly voluntary action by the railway companies that brought London time to Britain in general and Manchester in particular. The

North Western Railway introduced Greenwich time to its stations at Liverpool and Manchester in January 1846, and two years later this had been adopted by most railway companies in the north-west region.[10]

Thus it was in 1847 that the City Council of Manchester resolved to expend £100 to purchase a clock – along with certain unspecified meteorological instruments – and 'place them in an accessible position in the Town Hall … for the purpose of informing the public at all times what is Greenwich time'; all other clocks under the Corporation's control were set to and regulated by this clock. Initially this clock was placed under the care of Manchester's best known clockmaker, Peter Clare (1781–1851), a mathematician, anti-slavery campaigner and close associate of Joseph Dalton. Mancunians evidently persisted in using solar reckoning, however: when 'Quaker Clare' was offered declarations of solar time he would hastily reply: 'Dost not thee know that the sun has been notoriously wrong a long while, and that nobody minds him now? I'll tell thee what the time is by my clocks.' After Clare's death, the Council decided in 1852 to opt instead for astronomical time-keeping methods and spent £120 on a transit telescope, sidereal clock and chronometer for the purpose.

The first Astronomer to the Corporation was the Baptist minister Reverend Henry Halford Jones, who had long contributed astronomical information to Manchester's almanacs and occasional astronomical papers to the MLPS and RAS (of which he was member and Fellow respectively). Installing the instruments in an observatory next to his house, Jones kept Manchester's clocks regulated with unprecedented precision by using a pendulum device that needed little compensation for weather conditions; as a tacit perk of the position, he was also able to use the transit telescope to undertake his own private astronomical research.[11] After Jones's death in late 1858 the post of Astronomer to the Corporation naturally fell to another Manchester FRAS, Baxendell inheriting Jones's astronomical duties and instruments in February 1859.

From several other points of view, the year 1859 was a turning point in Baxendell's career, turning it from private observer to civic sage. It was then that he became MLPS secretary, serving in that role until 1885, and serving as editor of its *Memoirs* till his death. Most importantly for our purposes, it was the year in which Baxendell helped to found a specialist 'Manchester Literary and Philosophical Society – Physical and Mathematical Section' within the MLPS. During the winter months of the years that followed, it was to this small erudite body – numbering half a dozen – that Baxendell presented his astronomical and meteorological observations, notably those that Balfour Stewart judged to be of crucial importance in linking the periodic variations of sunspots and terrestrial weather. While Baxendell's attention to such cyclic phenomena was undoubtedly primed by decades of studying periodic behaviour in remote stars, what was it that prompted him to reconnect meteorology and astronomy some 24 years after he had left the marine service?



Balfour Stewart, Professor of natural Philosophy at Owens College, Manchester, 1870–87

Two major events in the autumn of 1859 inspired British attempts to develop a 'science' of meteorology, long treated as a natural history of collecting climactic facts and figures. A huge solar flare on 1–2 September 1859 brought, as we shall later see, magnetic storms that had extraordinary meteorological and electrical consequences around the world. More catastrophically, however, on 25–26 October that year a powerful tempest brought chaos to much of Britain, causing widespread destruction of railways and buildings. Most specifically it produced one of the most savage storms ever to strike the Irish Sea, wrecking the steamer *Royal Charter* on the Isle of Anglesey, just off the north Welsh coast. The ensuing loss of 459 lives and a huge cargo of gold *en route* from Melbourne to Liverpool shocked even the most hardened Victorian stoic. It prompted Rear-Admiral Robert FitzRoy to launch plans he had long nurtured for a system of what he was the first to call weather 'forecasts'. Two years later Fitzroy's cautionary storm warnings were not only sent to the Admiralty, ports and insurance companies, but published in national newspapers too.

Yet the storm-warning services did not bring Fitzroy great credit among his employers at the Board of Trade's meteorological board. They eventually instructed him to cease his controversial forecasting as it was beyond the bounds of his duties as they conceived them. Already suffering from difficult personal circumstances, Fitzroy committed suicide in April 1865 rather than witness the end of his life-saving work.[12] As an erstwhile sailor, Baxendell responded in sympathy by publishing a private pamphlet (drawn from a paper he had read to the MLPS) vigorously protesting against cancellation of the storm warnings.[13] When the Royal Society took over the supervision of the meteorological department six years later it refused to deal with forecasts, and indeed Baxendell's hostility to its policies probably explained his comparatively late election as a Fellow of the Royal Society in 1884.[14]

During the 1860s, and until his departure to Southport in 1871, Baxendell's commitment to utilitarian causes was manifest in many areas beyond that of storm warnings. A major concern was to determine the influence of meteorological conditions on public health and communicate the anticipated consequences to civic authorities. For example, his warning of an impending dry summer in 1868 assisted the Manchester Corporation Water Works to regulate water supply so as to pre-empt the worst consequences of drought.[15] Moreover, Baxendell took his astronomical duties as being more than just the regulation of Mancunian clocks to Greenwich Time; this was in any case a sinecure once railway expansion had brought an effectively instantaneous telegraph link between London and the north west. His long term aim was to enhance weather forecasting by using his astronomical skills to identify cyclical correlations between solar phenomena and terrestrial meteorology.

Baxendell and the development of astro-meteorology

During the 1860s, Baxendell's presentations to the MLPS ranged very broadly in their cosmic endeavours. He sought to identify correlations between temperature and pressure in the seasonal variations of Europe and Asia, later in the decade attempting to find links to the moon's orbit and to variations in the earth's magnetic field. For example, in a paper communicated to the Physical and Mathematical Section on 5 March 1863 he noted from measurement data at Greenwich in the period 1848–60 that the pattern of variation in solar radiation could be correlated to records of terrestrial temperature if the pattern of solar spot frequency was factored in to explain the discrepancies.[16] Lured by publications in the RAS *Monthly Notices* to study the periodical variations of sunspots (as a possible correlate of stellar variability),[17] his plan was to make a more systematic study of whether variation in the number and size of the sun's (cooler) surface spots could explain the variation in terrestrial temperatures at Greenwich and elsewhere. This project generated considerable interest in the winter of 1867–8, and later, especially when published by the MPLS in 1871.

On 10 October 1867 Baxendell read the first part of a paper 'On solar radiation' to the MLPS Section.[18] He revealed the enormous difficulties of attempting to draw together data on solar activity gathered by different observers using black-bulb thermometers that he needed to fulfil his long-term ambitions for weather forecasting. Of the 'perplexingly anomalous and unsatisfactory' results he had obtained from Greenwich he related that:

> Although observations of solar radiation have now been regularly made for several years at various public observatories, and by many amateur meteorologists, I am not aware that any useful or important result has yet been deduced from them. It seems to be generally supposed that the disturbing influences which affect the indications of the black-bulb thermometer are so uncertain and irregular in their action as to render it almost hopeless to expect that any new and valuable result can be obtained from them. On comparing sets of observations made by different observers, the most startling, and discouraging discrepancies are often found to exist, for which, in the absence of any information as to the exact circumstances under which observations were made, it is impossible to account satisfactorily.[19]

Fortunately Baxendell had recently been given volumes of observations of solar radiation and temperature at Oxford for 1858–64 by the University's Radcliffe Observer, Revd Robert Main FRS. Although he had not completed his analysis of the correlation for this data set, he felt that his results were 'sufficiently curious and remarkable' that he should draw them immediately to the attention of fellow researchers, albeit with a view to devising and adopting 'more reliable and systematic methods'. Showing the temperature and solar radiation figures in graphical form next to observations of sunspots for the same period revealed two curves of 'strikingly' similar form. For Baxendell this was 'conclusive' evidence that a connection existed between the two classes of the phenomena.[20]

Not all in Baxendell's expert audience in the MLPS Physical and Mathematical Section were able completely to confirm his results. One such was the section's secretary, the cotton-spinner George Vernon, like Baxendell an FRAS but also a Fellow of the Meteorological Society. On 26 November he reported that his own 11-year pattern of solar radiation observations made at Old Trafford produced a distribution that did not 'quite agree' with Baxendell's. Vernon did at least confirm the general correlation adding, in bucolic mood, that the greatest relative effect of solar radiation was in the spring in accordance with the 'very rapid growth of vegetation' that Manchester saw during that season.[21]

On New Year's Eve 1867 the Revd Thomas Mackereth FRAS, FMS, a schoolmaster in Salford and resident of Eccles, offered two papers to the Physical and Mathematical Section, explicitly inspired by Baxendell's work and indeed assisted by him. The first of these investigated the reliability of methods employed by the Oxford observers in his presentation of 'A comparison of solar radiation on the grass and at six feet from the ground'. As the Corporation of the Borough of Salford had recently installed a meteorological station in front of its Town Hall he used the roof apex of its shade-stand six feet above ground as an ideal location for his solar radiation thermometer; for a comparative study he fixed a similar thermometer in a comparable position at Eccles. At first he was most struck by the discrepancy in results between the elevated thermometers and those on nearby grass, but achieved much better correlations using a thermometer placed *in vacuo* on the grass. Mackereth thus concurred with Baxendell that 'some definite principle' was required in the placing of solar thermometers to attain any rigorous results.[22]

Mackereth's second paper presented solar radiation observations that Baxendell had encouraged him to make at Eccles, especially given that Mackereth's thermometers had long been set up much like those in Oxford. Although presenting his results in the same format as Vernon, Mackereth found his results for Eccles matched Baxendell's from Oxford rather more closely than Vernon's. Given his close association with Baxendell, it is perhaps not surprising that Revd Mackereth anticipated the match would have been 'more striking' still had he extended his observations over a longer period.[23]

A month later, on 28 January 1868, Baxendell read the second part of his paper 'On solar radiation' in which he more thoroughly presented his case for a connection between solar radiation and terrestrial temperature, making various seasonal corrections for the transmission of sunlight through water vapour in the atmosphere. He was now also able to assimilate Mackereth's results for Eccles, extending as they so usefully did two years beyond the Oxford series. Baxendell inferred from the results:

> It appears, therefore, that the calorific intensity of the sun's rays continued to diminish for two years after the termination of the Oxford series; and as the observations of Schwabe, Wolf, Balfour Stewart and others have shown that the frequency of solar spots also diminished during these two years, the probability that a close connexion exists between the two phenomena is considerably increased by the results of Mr Mackereth's short but valuable series of observations.

Once again a key feature of Baxendell's argument was to show closely congruent curves between the two sets of data, thus using the weather at Eccles and Oxford to generalize at a cosmic level about the processes linking solar spots to terrestrial effects of solar radiation.[24]

Published by the MPLS in 1871, this paper made a great impact on the newly arrived Professor of Natural Philosophy at Owens College, Manchester, Balfour Stewart – and not just for reasons of collegial mutual citation. As Stewart said in his obituary of Baxendell for *Nature* in October 1887, notwithstanding the errors of detail:

> Baxendell's contributions to meteorology are very important, and in one branch of this science, he may claim to be the pioneer. In 1871, from an analysis of eleven [*sic*] years' observations of the Radcliffe Observatory, Oxford, he came to the conclusion that the forces which produce the movements of the atmosphere are more energetic in years of maximum than in years of minimum sunspot activity. This conclusion has since been confirmed by other observers.[25]

Stewart had to admit, of course, that Baxendell's work was highly contentious since not all observers had been able to confirm his conclusions. Indeed, hinting at the carping of Richard Proctor, Stewart reported that:

> We have heard it objected that Baxendell generalized from a comparatively small number of observations, but in a question like this such a procedure is essential to the pioneer. His task is to deduce with a mixture of boldness and prudence something of human interest out of the mass of observations already accumulated, and thus to stimulate meteorologists not only to go on with their labour, but to cover more ground in the future than they have covered in the past. Baxendell's procedure in this respect has been abundantly justified by the fact that many other men of science are now following in his footsteps.

As we shall see, Stewart himself was one of those who followed in Baxendell's footsteps, having already become a major scholar on the theory and observation of sunspots before he arrived at Manchester in 1870.

Balfour Stewart: taking heavy weather from Kew Observatory to Owens College

Although more of a high profile public figure than Baxendell, the Edinburgh-born and educated Balfour Stewart has won relatively little attention from historians for his meteorological work or role in Manchester science.[26] Yet as Superintendent of Kew Observatory in London, 1859–70, and as Professor of Natural Philosophy at Owens College, Manchester, 1870–87, he was widely held as an authority on both astronomy and meteorology. Stewart enjoyed particularly close associations with Norman Lockyer (founding editor of *Nature*), Peter Guthrie Tait (Professor of Natural Philosophy at Edinburgh University)

and Arthur Schuster who was student (1871–3), assistant (1875) then colleague at Owens College, taking up the Langworthy Professorship of Physics from 1881. Like Baxendell, however, he often took on the scientific establishment in principled conflicts that had negative consequences for his career; indeed Stewart generally fared ill in his conflicts with patriarchal Sir Edward Sabine (President of the Royal Society), and with uncooperative field-station observers around Britain. Most troublesome perhaps were Richard Proctor and Robert H. Scott of the Meteorological Office, who both repeatedly challenged claims by Stewart and his allies that they had identified close connections between terrestrial weather and solar turbulence.

Arthur Schuster, Langworthy Professor of physics at Owens College, 1881–1907

Two months before the wrecking of the *Royal Charter*, and rather less lethal, was the globally visible spectacle of a huge solar flare on 1–2 September 1859. This generated a magnetic storm so intense that aurorae normally seen only at the poles were unusually visible near Rome and Hawaii. Telegraph lines around the world went haywire, garbling messages, giving electric shocks to signal-men across the telegraph network and setting fire to telegraphic apparatus in Norway.[27] Occurring just after Stewart arrived at Kew Observatory in south-west London, he was well equipped to observe and record precisely how major changes on the sun's surface could have a sudden and substantial effect on terrestrial life.

Kew Observatory was well placed to monitor this relationship since Stewart's boss there, now Major Edward Sabine, had for some years been convinced that sunspots were linked to changes in the earth's magnetism. The major difficulty in exploring this clue to solar influence on terrestrial conditions was that astronomers could not agree whether it took ten years or 11.11 years for sunspots to circulate around the sun's surface.[28] The period of the sunspot cycle long remained a point of contention, especially in later speculations that Stewart sought to make about links between sunspots and the weather. In addition to calibrating thousands of thermometers and barometers sent to him from field-stations around the country, from 1862 Stewart pursued Sabine's programme of solar meteorology, monitoring the motion and size of sunspots with the photoheliograph installed at Kew for the purpose of mapping the weather on the sun's surface. Two years later Stewart identified a possible explanation for sunspot cycles in planetary influence: sunspots were generated at points of the sun in opposition to nearby planets Venus and Mercury, and grew in size as the planet orbited away from them.[29] Such speculative claims were queried sharply by Richard Proctor, however.[30]

The increasingly ambitious Stewart next turned Kew into a laboratory for studying how the planets might interact with the sun. From 1865 he collaborated with Peter Guthrie Tait, a fellow Edinburgh graduate, in studying how discs spin to a halt in a vacuum. They claimed to have found friction in the cosmic ether – key to understanding how energy could move across empty space between planets and the sun. Others such as George Gabriel Stokes, Secretary of the Royal Society, saw rather more mundane sources of friction at work. Trials were continued in the 1870s, probably with Stewart's students at Manchester, involving the youthful J. J. Thomson, but never achieved conclusive results.[31]

Despite the controversies, Stewart began to collaborate in 1868 with scientific journalist and amateur astronomer Norman Lockyer to popularize the connection that he claimed must exist between sunspots and earthly weather. In the article they co-authored for *Macmillans Magazine*[32] they tellingly did not use Stewart's data from Kew Observatory. Rather they relied on the 'unconfirmed' testimony of an observer in Manchester – Joseph Baxendell – that terrestrial temperatures were affected by sunspots.[33] Combining this with evidence of concurrent planetary influences, they moved quickly to conclude that:

> the different members of our [solar] system are more closely bound together than has been hitherto supposed. Mutual relations of a mathematical nature we were aware of before, but the connexion seems to be much more intimate than this – they feel, they throb together … [and] something of this kind might be expected if we suppose that a Supreme Intelligence … pervades the universe, exercising a directive energy capable of comparison with that which is exercised by a living being.[34]

Stewart seems to have made this grandiose claim for a divinely unified meteorology of the cosmos to win support for Kew Observatory to become the programme's central body. Since the previous year his prospects of achieving this aim had been enhanced by the government's restoration of its Meteorological Committee to quell the controversy that followed its abandonment of 'storm warnings'.

Stewart was appointed Secretary to this Committee, and secured for Kew the status of 'Central Meteorological Observing Station'. From this vantage point he could co-ordinate the results of the weather stations around the British Isles with the results of solar observations. Yet Stewart's heavy-handed attempts to refashion the Meteorological Committee's system of weather surveillance to meet his 'cosmical' agenda soon resulted in disastrous conflict with Sabine.

As we know from the later testimony of Stewart's junior colleague at Manchester, Arthur Schuster, in his *Biographical fragments*, Sabine saw Kew's facilities as serving other purposes.[35] By 1869 Stewart readily had recourse to the columns of Lockyer's new journal *Nature* to complain about his treatment by Sabine. There he bewailed how the scientific worker had to 'work with the one hand and fight with the other', and railed against the 'deplorable' lack of co-operation and systematic practices among dispersed observers.[36] By 1870 his bid to marshal Kew's resources into a scheme of cosmical meteorology was untenable and he (effectively) resigned his Superintendency by taking up the Chair of Natural Philosophy at Owens College, Manchester.[37]

Owens College and *The Unseen Universe*

Although Manchester had almost none of Kew's technological advantages, it at least offered Stewart direct communication with Baxendell through meetings of the MLPS Physical and Mathematical Section. It also offered Stewart a forum for research free from Sabine's constraints and a captive student audience that could serve as a workforce for him. In his inaugural address at Owens College, Stewart declared that:

> [I]t is of great importance to know whether the earth's climate and atmosphere are influenced in any way by the changes taking place in the atmosphere of the sun. Such a connection has not yet been traced, but it has hardly been sought for in a proper manner … I feel convinced that meteorology should be pursued in connection with terrestrial magnetism and solar observations; and were a well considered scheme for solving this great problem fairly introduced, I am sure that scientific institutions and individuals throughout the country would do all that they possibly could do to promote this most important branch of physical research.[38]

Stewart's researches and speculations were prominent, especially his campaign for a new publicly-funded observatory – apparently to be run by himself – conducted both in interviews with the Devonshire Commission[39] (Secretary, Norman Lockyer) and in polemical articles for *Nature* (editor, Norman Lockyer). Yet despite the popular interest during the 1870s in both sunspots[40] and weather forecasting,[41] these stage-managed demands came to nothing. A similar fate befell his pleas – akin to Baxendell's – that all weather data be published unprocessed so that his universalizing techniques for reducing observations could transcend the local idiosyncrasies of other observers' programmes.[42] So instead of a single 'well considered scheme', co-ordinated from his Owens College laboratory observatory, there emerged a multiplicity of localized efforts around the world, each with their own divergent agendas, resources and techniques.

Cultural anxieties about and responses to weather have long been appropriated by the ambitious;[43] indeed sunspot-weather linkages could be 'appropriated' for a number of rather different concerns. British colonial administrators, for example, had long been preoccupied with famine and flood relief;[44] so after identifying a similar 11-year cycle in the monsoon rains of Ceylon (Sri Lanka), Lockyer tried to persuade the Indian Meteorological Department (opened in 1875) that India's regular climatic variations could easily be correlated with sunspot cycles. This would provide him with financial support for his own laboratory and a chance to prove the utility of his solar work.[45] For Stewart and Tait, the linkages could even be harnessed to 'prove' the compatibility of science and religion, as was claimed in a treatise they published in 1875 (initially) anonymously entitled *The unseen universe*. Here is how a reviewer in *Nature* summarized one of its arguments:

> a whole series of tremendous meteorological phenomena, such as hurricanes in the Indian Ocean, happen because certain positions of Mercury and Venus affect the sun's atmosphere, causing spots … and th[is] condition of the sun affects the earth. Like the complicated series of effects which follow the pulling of the trigger of a gun, the effects are utterly disproportionate to their causes. Man is a machine of this unstable kind … May not other beings [thus] be capable of touching what we may call the hair-triggers of the universe? Whatever these agencies are, angels or ministering spirits, they certainly do not belong to the present visible universe.[46]

Significantly, the work of Scottish natural philosophers was cited as evidence on the management of weather by cosmic spirits in the ether, especially Stewart and Tait on discs rotating *in vacua*![47] In fact their co-authorship was obvious prior to confirmation in 1876 in the fourth of the 14 editions that appeared over 13 years.[48] The critical debate around this much-read book was intense;[49] yet while reviewers were generally sceptical of its arguments – the *Nature* reviewer doubting that the 'invisible universe' could be supported eternally by energy *dissipated* in the 'visible' – none challenged evidence of a link between sunspots and weather.[50] Other than to confirm Stewart and Tait's indefatigable piety, the only unequivocal effect of *The unseen universe* was thus perhaps to give publicity to cosmic meteorology – but not enough, as it turns out, to secure its universal credibility.

The disintegration of universal meteorology from the late 1870s

Within a few years, the recurrent proliferation of independent investigations had produced troublesome disagreements. While in some locations a positive correlation was found between cycles of sunspot intensity and key meteorological parameters, for others precisely the *opposite* correlation was claimed: Balfour Stewart admitted this of Meldrum's work on rainfall at a meeting of the Manchester Literary and Philosophical Society in 1880 (see below). Worse than this, at about the same time, the Indian Government's chief meteorologist announced he could not verify Lockyer's claim that droughts regularly followed sunspot minima.[51] Such evidence of grand correlations failed and global forecasts compromised were gleefully publicized by Richard Proctor, one of Lockyer's most relentless critics.[52]

Proctor reserved equal sarcasm for Baxendell, whose 1876 MLPS paper sought to link rainfall and wind direction to sunspot variations:[53]

> From records of rainfall kept at Oxford it appears that more rain fell under west and southwest winds when sunspots were largest and most numerous than under south and south-east winds, these last being the more rainy winds when sunspots were least in size and fewest in number. This is a somewhat recondite relation, [but] at least proves that earnest search has been made for such cyclic relations as we are considering.[54]

And, as Proctor cheerfully pointed out from other researches by Baxendell, the rainfall-wind relation at St Petersburg was observed to be the precise opposite to that at Oxford.[55] Most damning of all, though, Proctor highlighted sunspot watchers' inability to agree even on the period of sunspot cycles to which correlations should be drawn – these varying in some cases from less than eight years to more than 18.

Stewart's response to such criticisms was to admit that sunspot-weather linkages were of a more complex and multiple character than previously suspected. In 1880, having secured – with unusual diplomacy – data on European rainfall from his successor at Kew (George Whipple), Stewart showed that sunspot-weather correlations were subject not to a single cycle of c. 11 years, but to two distinct periodicities of nine and 12 years.[56] This did not impress Robert Henry

Scott, Stewart's successor as Secretary to the Meteorological Council (formerly Committee). In his 1883 textbook *Elementary meteorology*, Scott contended that 'next to no progress' had been made in the 'cosmical' branch towards understanding the agencies that produced the 'various phases of weather'.[57] Despite Stewart's resolution of complex multiples, Scott devoted an appendix specifically to demolishing the straw target of the 11-year sunspot-weather cycle[58] that he alleged was claimed by the 'high authority' of Meldrum and Stewart. Insofar as the connection was 'not sufficiently understood to justify prediction' and there were 'contradictory conclusions' on the nature of these connections, Scott concluded that it could 'scarcely be said that the close relation between solar and terrestrial phenomena is capable of accurate demonstration'.[59] By 1884, even Stewart's best-informed allies were conceding these points. Professor E. Douglas Archibald, Professor of Mathematics in the Bengal Education Department, who for many years prepared three-day weather forecasts for *The Times* in London, frankly admitted that at present 'we are considerably in the dark about the whole question'.[60]

In 1885 Stewart had retreated (with Schuster's assistance as Langworthy Professor of Physics from 1881) to older speculations on relations between geomagnetism and wind, *viz*. that air currents electrified in the upper atmosphere – perhaps by solar radiation from sunspots – were a major cause of terrestrial magnetic disturbance. Ironically, this was a sideline of his duties as Secretary of a Committee of the British Association for the Advancement of Science set to rework the methodologically-challenged tabulations of the now deceased Sir Edward Sabine.[61] But then Stewart himself died suddenly in late 1887 (only a few months after writing Baxendell's obituary) with the committee still squabbling about the techniques for so doing, a sadly appropriate ending for one unable to secure broad or permanent assent for his views or practices.

After Stewart's demise, and alongside mainstream activities in electrical and X-ray physics,[62] Arthur Schuster built up a major school of meteorology at Manchester that drew strongly on Stewart's prior researches. Schuster adopted a much more limited vision for the field, though, especially now that 'cosmic' meteorology was in decline. He devoted his study of periodicities to the upper atmosphere and to variations on terrestrial magnetism, and was rather more cautious about claims concerning solar influences on the weather.[63] Schuster's caution paid off as he won himself a central place in the meteorological organization of the Royal Society, and thus at the head of the UK's meteorological management – something that neither Baxendell nor Stewart had ever truly accomplished. Schuster's Royal Society obituarist, his protégé G. C. Simpson, argued plausibly that Schuster was responsible for introducing meteorology as a university subject in the UK. In 1905 he set up a small meteorology group within the Physics Department at the University of Manchester and placed Simpson in charge as Britain's first higher education lecturer in the field. This group reorganized the meteorological station in Manchester's Whitworth Park, and, in order to pursue Schuster's agenda of investigating the upper atmosphere, established a kite and balloon station on the hills near Glossop in Derbyshire – where the young Ludwig Wittgenstein experimented in aeronautics until deciding to become a philosopher.[64] From Baxendell's and Stewart's rather controversial and localized nurturance of cosmical meteorology in the preceding century a more 'orthodox' species of terrestrial meteorology spread from Manchester across the country throughout the course of the twentieth century.

Conclusion: gregarious cosmic universalism or comically egregious localism?

For two decades from the early 1860s, Manchester and its Literary and Philosophical Society were the centre of a campaign to launch a cosmical form of meteorology with the fruitful indirect consequences described above. This particular form of civic science, barely hinted at in Kargon's standard account of Manchester's scientific life, reveals particular kinds of intensive networking between meteorologists who were neither simply amateurs nor professionals, nor working within easily recognizable boundaries of disciplinary activity within the physical sciences.[65] Meteorology was to that extent just as much the 'gregarious' science in nineteenth-century north-west Britain as Jim Fleming has shown it to be of nineteenth-century America.[66] The political problems encountered by both Baxendell and Stewart, however, were sufficiently egregious that, in the form they pursued it, it died with them in 1887.

But lest we think of the short-lived and apparently parochial attempt at a universal meteorology as a failed Victorian fad of deluded camaraderie, it is worth noting that just the sort of correlations pursued by Baxendell, Stewart *et al* are today used by a London-based organization called *Weather Action*. In 1994 it used correlations with a *22-year* sunspot cycle to makes private forecasts 'successful' enough to be self-financing (with an annual turnover of £100,000).[67] Although highly controversial still, this organization uses the well-guarded 'Solar Weather Technique' developed by astrophysicist and meteorologist Piers Corbyn to make long-term forecasts that are purchased by insurance companies and other organizations. Such secrecy and commercialization would doubtless have been anathema to the openness and civic altruism of the Mancunian gentlemen discussed above. More than mere anachronistic speculation, such a contrast should remind us of how much has changed in science in the last 150 years, a point that is best understood by regionally specific studies of science such as this. Moreover, bearing in mind the extraordinary developments of interdisciplinary science in the twenty-first century, historians might consider what other uniquely Mancunian activities of Victorian natural science might prove to be similarly revelatory to those seeking to break away from the strait-jacket of twentieth-century conceptions of how knowledge-based specializations emerged.

Notes

1. Part of this paper is drawn from chap. 7, 'Balfour Stewart, exact meteorology and the physical laboratory at Owens College, Manchester', of my doctoral thesis: 'Precision measurement and the genesis of physics teaching laboratories in Victorian Britain' (unpub. PhD, University of Kent at Canterbury, 1989), advisor Crosbie W. Smith. An early version of this paper was presented at the HSS annual meeting in New Orleans, 1994.
2. This activity has often been misleadingly subsumed under the heading 'solar physics': see K. Hufbauer, *Exploring the sun: solar science since Galileo* (Baltimore/London, 1989), p. 49ff.
3. These MLPS publications combined in 1888.
4. The Mancunian roles of Baxendell, Stewart and Schuster are discussed (without reference to mutual meteorological interests and research) in R. Kargon, *Science in Victorian Manchester* (Manchester, 1977), pp. 31, 35, 60, 74–8, 81–4, 195–6, 212–36.
5. 'The Late Mr Joseph Baxendell', *Manchester Guardian*, 10 Aug. 1887, p.5 col. h.
6. Baxendell's family life was bound up closely with astronomy. As a child he had been introduced to this study by his mother Mary [*née* Shepley] and in 1865 he married Mary Anne Pogson, the sister of Norman Pogson, government astronomer for Madras and fellow observer of variable stars. See J. Bottomley, 'Memoir of the late Joseph Baxendell, F.R.S., F.R.A.S.', *Proceedings of the MLPS*, 4th ser., 1, pp. 28, 30.
7. 'On the variability of ë Tauri', *Monthly Notices of the RAS*, 9 (1846–8), pp. 37–8.
8. J. Baxendell, 'On the variability of 13 Lyrae', *Monthly Notices of the RAS*, 16 (1855–6), p. 201; 'On the period and changes of á Herculis', *Monthly Notices of the RAS*, 16 (1855–6), pp. 201–4; 'On the variable star B.A.C. 3345 (R. Leonis)', *Monthly Notices of the RAS*, 17 (1856–7), p. 235; 'On the variability of 30 Herculis, *Monthly Notices of the RAS*, 17 (1856–7), pp. 266–7.

Notebooks and other documents pertaining to Baxendell's observations on variable stars are held by the Royal Astronomical Society Archives: http://www.ras.org.uk/index.php?option=content&task=view&id=114, accessed 6 Sep. 2005.

9. J. Baxendell, 'On a new variable star (R. Sagittae)', *Proceedings of the MLPS*, 3rd ser., 1 (1857–60), pp. 197–99; 'Observations of the Zodiacal Light', *Proceedings of the MLPS*, 1 (1857–60), pp. 222–5.
10. http://wwp.greenwichmeantime.com/info/railway.htm, accessed 6 Sep. 2005.
11. Baxendell obituary, *Manchester Guardian*, 10 Oct. 1887. On Clare and the history of Quakers in Manchester see http://www.hardshaweastquakers.org.uk/histories/historymanchester.php. For Jones see 'Obituary', *Monthly Notices of the RAS*, 19 (1859), pp. 119–20.
12. A. McConnell, 'FitzRoy, Robert (1805–1865)', *Oxford Dictionary of National Biography* (Oxford, 2004) [http://www.oxforddnb.com/view/article/9639].
13. J. Baxendell, *On the recent suspensions by the Board of Trade of cautionary storm warnings* (privately published, 1867). In the session 1866–7 Baxendell presented three papers on this subject to the MLPS: 'On the recent suspensions by the Board of Trade of cautionary storm warnings'; 'On Dr Buys Ballot's weather signal', and 'On storm warnings'. See Bottomley, 'Memoir', p. 44; and K. Anderson, *Predicting the weather: Victorians and the science of meteorology* (Chicago, 2005), pp. 128, 142.
14. C. W. Sutton, 'Baxendell, Joseph (1815–1887)', rev. Katharine Anderson, *Oxford Dictionary of National Biography* (Oxford, 2004) [http://www.oxforddnb.com/view/article/1727].
15. Later at Southport his advice to take precautionary measures against a smallpox outbreak was overlooked and an epidemic ensued: Bottomley, 'Memoir', p.32.
16. J. Baxendell, 'On periodic changes in the magnetic condition of the Earth, and in the distribution of temperature on its surface', *Proceedings of the MLPS*, 3 (1864), pp. 251–60.
17. 'Note on Prof Wolf's latest results on solar spots', *Monthly Notes of the RAS*, 21 (1861), pp.141–3.
18. J. Baxendell, 'On solar radiation, Part I', *Memoirs of the MLPS*, 3rd ser., 4 (1871), pp. 128–39.
19. *Ibid.*, p. 128.
20. *Ibid.*, pp. 130–9.
21. G. V. Vernon, 'Solar radiation observations, made at Old Trafford, Manchester', *Memoirs of the MLPS*, 3rd ser., 4 (1871), pp. 139–42.
22. T. Mackereth, 'A comparison of solar radiation on the grass and at six feet from the ground', *Memoirs of the MLPS*, 3rd ser., 4 (1871), pp. 142–3.
23. T. Mackereth, 'Solar radiation observations, made at Eccles, near Manchester', *Memoirs of the MLPS*, 3rd ser., 4 (1871), pp. 144–7.

24. J. Baxendell 'On solar radiation, Part II', *Memoirs of the MLPS*, 3rd ser., 4 (1871), pp. 147–55, esp. p. 152.
25. B. Stewart, 'Joseph Baxendell, F.R.S.', *Nature*, 36, 1887, p. 585. These passages were muted in the version of the otherwise largely similar obituary that Stewart wrote for the Royal Society: B[alfour] S[tewart], 'Joseph Baxendell', *Proceedings of the Royal Society of London*, 43 (1887), pp. iv–vi.
26. The exception is discussion of his priority disputes with Robert Kirchhoff about the origins of spectrum analysis; see D. Siegel, 'Balfour Stewart and Gustav Robert Kirchhoff: two independent approaches to Kirchhoff's radiation laws', *Isis*, 67 (1976), pp. 565–600.
27. Cited in R. Proctor, *The sun: ruler, fire, light and life of the planetary system* (1871), pp. 207–9.
28. See N. Reingold's entry on Sabine in the *Dictionary of Scientific Biography*; Hufbauer, *Exploring*, pp. 46–51; Proctor, *The sun: ruler of the planetary system* (2nd ed., 1872), p. 195ff.
29. B. Stewart, 'On sun-spots and their connection with planetary configurations', *Transactions of the Royal Society of Edinburgh*, 23 (1864), pp. 499–504. In the period 1865–73 Stewart published ten empirical papers on this and related subjects in collaboration with Warren de la Rue and Benjamin Loewy: see Royal Society Catalogue.
30. Proctor, *The sun: ruler of the planetary system*, pp. 218–9.
31. B. Stewart and P. G. Tait, 'Preliminary note on the radiation from a revolving disc', *Proceedings of the Royal Society*, 14 (1865), p. 90; *idem*, 'On the heating of a disk by rapid rotation *in vacuo*', pp. 339–43. Sequels to the lattermost were published in 1867, 1873 and 1878: see G. Gooday 'Sun-spots, weather and the unseen universe: Balfour Stewart's anti-materialist representations of "energy" in British periodicals', in G. Cantor and S. Shuttleworth (eds.), *Science serialized: representations of the sciences in nineteenth-century periodicals* (Cambridge, Mass./London; 2004), pp. 111–47.
32. J. N. Lockyer and B. Stewart, 'The sun as a type of the material universe', *Macmillans Magazine*, 18 (1868), pp. 246–57, 319–27. For further discussion of this essay and other aspect of how Stewart's religious commitments informed his physics, see Gooday, 'Sun-spots, weather and the unseen universe'.
33. *Ibid*., p. 256.
34. Lockyer and Stewart, 'The sun as a type of the material universe', p. 327.
35. Arthur Schuster, *Biographical fragments* (1932), pp. 208–9.
36. B. Stewart, 'Physical meteorology – its present position', *Nature*, 1 (1869), pp. 101–3, quote from p. 102.
37. Schuster, *Biographical fragments*, pp. 208–9 *et seq*.
38. B. Stewart, *Recent developments in cosmical physics* (privately published, 1870), copy in Manchester University Library.

39. See Stewart's interviews with the Royal Commission on Scientific Instruction and the Advancement of Science, 1872 and 1874.
40. See Hufbauer, *Exploring*, p. 48ff.
41. See Anderson, *Predicting the weather*.
42. See *First and second reports from the Royal Commission on scientific instruction and the advancement of science, with minutes of evidence, appendices and correspondence, together with a supplementary report and memorial, 1871–72* (Shannon, 1969), pp. 155–6. (The original was published in 1872 by HMSO in London.)
43. R. M. Friedman, *Appropriating the weather: Vilhelm Bjerknes and the construction of modern meteorology* (London, 1989).
44. For example, in 1873 the Secretary of the Mauritius Meteorological Society, Dr Charles Meldrum, reported cyclone-frequency in the Indian Ocean peaked at times of sunspot maxima; likewise the rainfall in Mauritius and Australia: Charles Meldrum, 'On a periodicity of cyclones and rainfall in connexion with the sunspot periodicity', *British Association Report* (1873), pp. 466–78.
45. A. J. Meadows, *Science and controversy: a biography of Sir Norman Lockyer* (1972), pp. 124–9.
46. [Anon.], '*The Unseen Universe*', *Nature*, 12 (1875), pp. 41–3; cf. pp. 143–6 of Anon. [Tait and Stewart], *The unseen universe* (1875).
47. *Ibid*. See especially p. 91, also pp. 111–18.
48. See P. J. Hartog, 'Stewart, Balfour (1828–1887)', rev. G. J. N. Gooday, *Oxford Dictionary of National Biography* (Oxford, 2004) [http://www.oxforddnb.com/view/article/26463].
49. As Tait later admitted, the responses to it varied from 'hearty welcome and approval' to 'the extremes of fierce denunciation' or 'lofty scorn': P. G. Tait, 'Dr Balfour Stewart', *Proceedings of the Royal Society*, 41 (1887–8), pp. ix–xi, esp. p. xi.
50. See review by William Clifford, *Fortnightly Review*, 23 (1876), pp. 776–93; and comments by 'E.C.' in *Fraser's Magazine*, 93 (1876), pp. 60–8; [Anon.], '*The Unseen Universe*', *Nature*, 12 (1875), p. 43.
51. Meadows, *Science*, p. 127.
52. R. A. Proctor, 'Sunspots and commercial panics', in *Rough ways made smooth: a series of familiar essays on scientific subjects* (London, 1880), pp. 26–31. I am grateful to Bernie Lightman for this reference.
53. Cf. J. Baxendell, 'On changes in the distribution of barometric pressure, temperature, and rainfall under different winds during a solar-spot period', *Memoirs of the MLPS*, 5 (1876), pp. 137–50.
54. Proctor, 'Sunspots and commercial panics', p. 27.
55. *Ibid*. This was almost certainly a slighting reference to J. Baxendall, 'On the distribution of rainfall under different winds, at St Petersburg, during a solar spot period', *Proceedings of the MPLS*, 11 (1872), pp. 135–6.
56. B. Stewart, 'On the long-period inequality in rainfall', *Memoirs of the*

MLPS, 3rd ser., 7 (1882), pp. 161–9.

57. R. H. Scott, *Elementary meteorology* (1883), pp. 1–5.
58. *Ibid*., Appendix V, 'Note on the relation between sunspots and weather', pp. 392–4; for the increasingly complex character of Stewart's later analysis of multiple periodicities, see A. Schuster, 'Memoir of the late Professor Balfour Stewart', *Memoirs of the MLPS*, 4th ser., 1 (1888), pp. 253–72, esp. p. 264. The mathematics of periodicities later became one of Schuster's specialities.
59. Scott, *Elementary meteorology*, p. 393.
60. E. D. Archibald, 'On the connection between solar phenomena and climatic cycles', in A. Ramsay (ed.), *The scientific roll: a bibliography, guide and index to climate* (1884), pp. 17–37, 145–152; the quote is from p. 152. See Archibald's obituary in *Quarterly Journal of the Meteorological Society*, 40 (1914), pp. 79–80. For some particularly scathing criticisms of meteorology in the early twentieth century, see the discussion of cosmical meteorology by Cleveland Abbe of the US Weather Bureau in 'Meteorology', *Enyclopedia Britannica* (11th ed., 1911).
61. A. Schuster, 'On the connection between sunspots and terrestrial phenomena', *British Association Reports* (1884), pp. 446–63; 'Report[s] of the committee … appointed for the purpose of considering the best means of comparing and reducing magnetic observations', *British Association Reports* (1885), pp. 65–89; *British Association Reports* (1886), pp. 64–99; *British Association Reports* (1887), pp. 320–35.
62. See P. J. Davies, 'Sir Arthur Schuster, FRS, 1851–1934' (unpub. PhD, University of Manchester Institute of Science and Technology, 1983), which does not discuss Schuster's meteorological activities in detail.
63. A. Schuster, 'On the possible effects of solar magnetization on periodic variations of terrestrial magnetism', *Philosophical Magazine*, 46 (1898), pp. 395–402; 'The application of terrestrial magnetism to the solution of some problems of cosmical physics', *BAAS Report* (1898), pp. 745–7; 'On the investigation of hidden periodicities with application to a supposed 26-day period of meteorological phenomena', *Terrestrial Magnetism*, 3 (1898), pp. 13–41.
64. For six years Schuster even established, at his own expense, a Readership in Meteorology at the University of Cambridge: G. C. Simpson, *Obituary Notices of Fellows of the Royal Society*, 1 (1932–5), pp. 409–23. For Wittgenstein's early career in aeronautical engineering in Manchester see R. Monk, *Ludwig Wittgenstein: the duty of genius* (1990), pp. 28–35; K. Hamilton, 'Some philosophical consequences of Wittgenstein's aeronautical research', *Perspectives on Science*, 9 (2001), pp. 8–10.
65. Kargon, *Science in Victorian Manchester*.
66. J. R. Fleming, *Meteorology in America, 1800–1870* (Baltimore, 1990), preface.
67. P. Coyne, 'Could the sun be the main influence on our weather?', *New*

Statesman and Society, 18 Mar. 1994, p. 47. For information on Weather Action see http://www.weatheraction.com, accessed 6 Sep. 2005. For positive academic appreciation of Weather Action's work see Dennis Wheeler, 'A verification of UK gale forecasts by the "solar weather technique": October 1995–September 1997', *Journal of Atmospheric and Solar-Terrestrial Physics*, 63 (2001), pp. 29–34. See also mention of Piers Corbyn's work in the children's book: John Farndon, *1000 things you should know about Planet Earth* (2000), p. 49.